Intellimotion

Keeping up with California PATH Research in Intelligent Transportation Systems

Sensor Research at PATH

Inertial Sensors for Navigation Systems

Kirill Mostov
PATH Sensor Group

Accurate and cheap vehicle navigation systems are essential for many Intelligent Transportation Systems (ITS) applications. Systems such as those used in aircraft navigation cost several times the price of an average car, but do not provide the accuracy needed to navigate a vehicle within a narrow lane at speeds

John Bdzil, Jisheng Shi and Kirill Mostov testing "proof of concept" multisensor system

of 90 miles per hour. The navigation system being developed by PATH must provide measurements of absolute and relative position, velocity, and acceleration to automated vehicles. The system will eventually use inertial measurements, map matching, satellite positioning, and magnetic markers. We believe our system will set a standard for low cost and high accuracy navigation units.

We are in a unique position to accomplish this goal because of our close alliance with experts developing current sensor technology at UC Berkeley. During the past several years, Professors Boser, Howe, and Pisano of the Berkeley Sensor and Actuator Center (BSAC) and their graduate students have been working to implement this silicon surface micromachining technology in inertial sensors for PATH. The BSAC group has pursued new approaches in integrated technology, including innovative designs of sigma-delta accelerometers and vibrating gyroscopes. The group's designs are fabricated at the foundries of Analog Devices in Norwood, Massachusetts, and at other high quality manufacturing facilities. Last year Analog Devices began providing such sensors on a commercial basis, making it possible to build commercially viable systems for PATH.

Our group's effort is focused on developing vehicle navigation systems. The system level design is divided into four main tasks. The first task is to develop detailed specifications for the sensors and the design of the general architecture of the IMU (inertial measurement unit), including its mounting in a vehicle. The second task is the design of

continued on page 13

Crash Sensing Systems:

Recent Developments in Sensing Technologies for Automotive Occupant Restraint Systems

Ching-Yao Chan
PATH

A crash sensing system is the brain of an occupant restraint system. It detects the occurrence of a collision and determines the probable crash severity. At collision speeds beyond a predetermined threshold, the sensing system initiates the timely deployment of restraint devices to prevent or mitigate the potential injuries to occupants.

Passive occupant restraint systems, such as air bags, have become popular and standard equipment for new automobiles in recent years. Accident statistics show that air bags, which are widely accepted by consumers, provide effective occupant protection. Research has confirmed that air bags reduce driver deaths. Researchers have found 23 percent fewer deaths than expected in front and front-angle crashes of air-bag-equipped cars.

Crash sensing technologies are developing rapidly. In particular, single-point electronic sensors are being developed to replace the distributed system of multiple electromechanical sensors. This trend, driven by the cost savings resulting from the elimination of wiring and connectors between multiple units, demands that designers incorporate complex sensing algorithms in electronic sensors.

Electronic sensors offer several advantages over traditional mechanical, electrical, and magnetic sensors:
- Integration with inexpensive silicon-based micromachined accelerometers;
- Flexibility in implementing complex or multiple sensing algorithms;
- Capability for signal conditioning, self-testing and crash data recording; and
- Expandability for sensing synergy and multiple functionality.

The development of various sensing technologies and their applications in automobiles have created new opportunities and challenges for designers of vehicle safety systems. Various methods and strategies of combining various sensing components are proposed to enhance the performance of conventional crash sensing units. An integrated crash sensing system may include the following elements:
- An anticipatory or a predictive capability to evaluate the vehicle status and surrounding environment for assessment of collision hazards;
- A confirmatory and discriminatory intelligence to determine the type, condition, and severity of crashes:
- A deployment control means to select and activate an appropriate level of restraints at a proper timing for optimal occupant protection; and
- A method of communicating collision data to emergency services for prompt rescue efforts.

To accomplish the functional requirements of such an intelligent crash sensing system, the following obstacles must be overcome:
- Availability of reliable and robust sensing units and related components;
- Market acceptance of futuristic vehicle equipment and reduction of component costs;
- Development of intelligent algorithms to incorporate various sensing information into the functions of crash sensors;

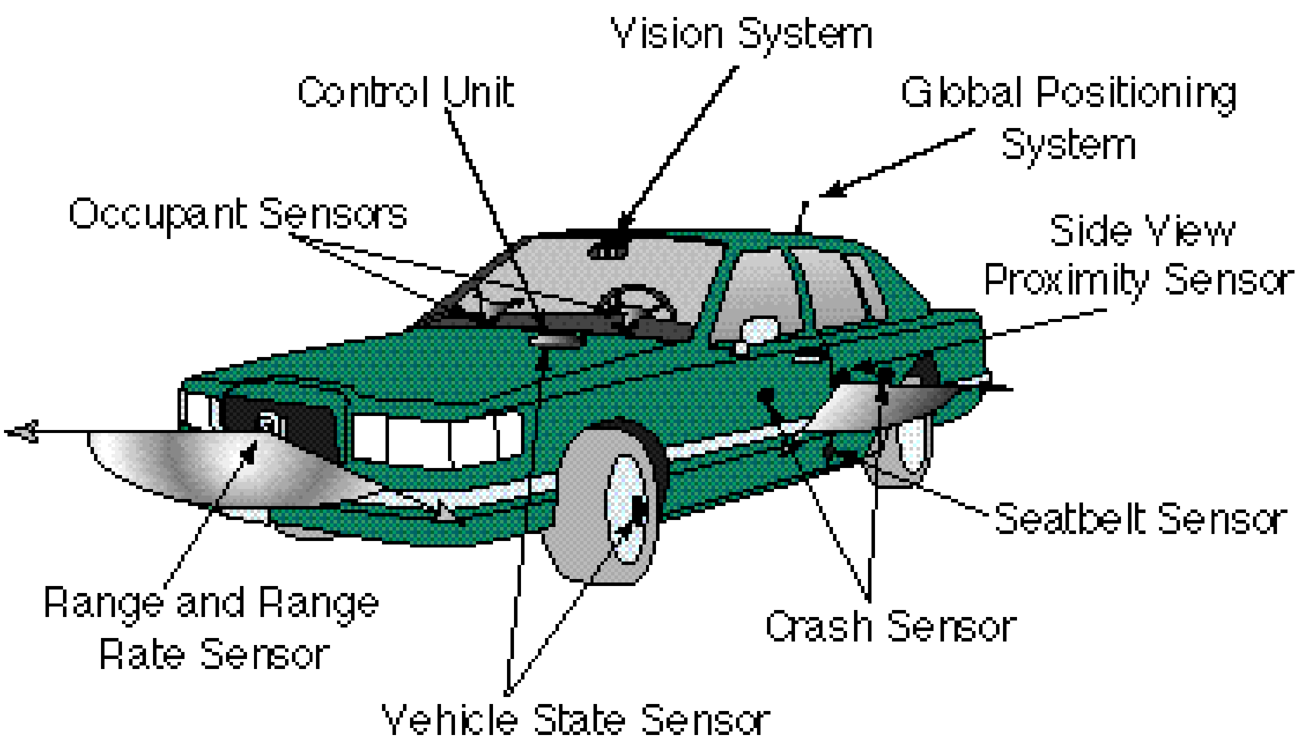
• Hardware architecture that allows communication and networking among various sensing components.

Recent developments in innovative products, such as occupant sensing devices and smart inflators, will enhance the performance of future occupant restraint systems. With continuing strong demands in vehicle safety, the technology of crash sensing will remain an exciting and a challenging field.

References

Ching-Yao Chan, PATH, and Fred Shokoohi, Morton International, "Sensing Problems in Automotive Occupant Restraint Systems," 1995 IEEE Symposium on Intelligent Vehicles, Detroit, Michigan, September 1995.

Ching-Yao Chan, PATH, "Integration of Sensor Technologies for Intelligent Occupant Restraint Systems in Automobiles," Second World Congress on Intelligent Transportation Systems, Yokohama, Japan, November 1995.



Vehicle with integrated crash sensing system

PATH Research Presented

Below is a list of some of the conferences or workshops where PATH sponsored research was, will be, or (in the case of TRB) would have been presented.

ITS America Annual Meeting

Houston, Texas, April 15-18, 1996

- Youngbin Yim, Paul Hellman, Brian Pfeifle "Evaluation of Radio Traffic Information."Thomas Horan, Eric Alm "An Assessment of ITS System Performance Assumptions and Implementation Barriers."
- ITS Systems Architecture: A Societal Issues Perspective, Mark Miller, moderating
- Thomas Horan and Joy Dalgren panelists
- Modeling for ITS Evaluation, Hong Lo, moderating. Bret Michael and Daniel Sperling panelists
- AHS Development: The Challenges, Steve Shladover, panelist
- Mark Hickman, Theodore Day "Advanced Information Technologies at California Transit Agencies."
- Bret Michael, Raja Sengupta, Datta Godbole "A Tool Framework for Assessing the Safety Properties of Automated Highway Systems."
- Ching-Yao Chan "Studies of Collisions in Vehicles Following Operation by Two-Dimensional Impact Simulations."

Transportation Research Board 75th Annual Meeting

Washington, D.C., January 7-11, 1996

Due to blizzard conditions in Washington during TRB, some of the following scheduled presentations were cancelled.

- Mark D. Hickman, Theodore Day "Assessment of Information Systems and Technologies at California Transit Agencies," *960711*
- Alexander Skabardonis, Karl Petty, Hisham Noeimi, Pravin Varaiya "The I-880 Field Experiment: Database Development and Incident Delay Estimation Procedures," *960961*
- Y.B. Yim, Jean-Luc Ygnace "Link Flow Evaluation Using Loop Detector Data: Traveler Response to Variable Message Signs," *960705*
- Mohamed A. Abdel-Aty, Ryuichi Kitamura, Paul P. Jovanis "Investigating the Effect of Advanced Traveler Information on Commuters' Tendency to Use Transit," *960672*
- Y.B. Yim "Evaluation Framework of ATIS Field Operational Test," *960704*
- Randolph W. Hal, Indrajit Chatterjee "Organizing for Intelligent Transportation Systems: Commercial Vehicle Operator Results," *960622*
- Steven E. Shladover "Technical Development within the National AAHS Consortium"
- Joy Dahlgren "In What Situations Do High-Occupancy-Vehicle Lanes Perform Better Than General Purpose Lanes?" *960293*
- Ted Chira-Chavala, Benjamin Coifman, Christopher Porter, Mark Hansen "Light-Rail Accident Involvement and Severity," *960612*
- Aemal J. Khattak, Konstadinos G. Goulias, Asad J. Khattak "Comparison of Traveler Perceptions Regarding Traffic Congestion and Route Selection Behavior Across Chicago, San Francisco, and Centre County," *960563*
- Amalia Polydoropoulou, Moshe Ben-Akiva, Asad J. Khattak, Geoffrey Lauprete "Modeling Revealed and Stated En-Route Travel Response to ATIS," *961087*
- M. Broucke, P. Varaiya "Theory of Traffic Flow in Automated Highway Systems," *960430*
- Bin Ran, H. S. Jacob Tsao "Traffic Flow Analysis for an Automated Highway System," *960232*
- Michael Cassidy "Identifying Unique Bivariate Relations in Highway Traffic," *960100*
- Matthew Barth, Feng An, Joseph Norbeck, Marc Ross "Modal Emissions Modeling: A Physical Approach," *960905*
- Hong K. Lo, Bin Ran, Bruce Hongola "Multiclass Dynamic Traffic Assignment Model: Formulation and Computational Experiences," *961108*
- Robert B. Noland, Kenneth A. Small, Pia Maria Koskenoja, Xuehao Chu, "Simulating Travel Reliability," *960450*

International Congress of IFAC (International Federation of Automatic Control)

San Francisco, California, July 1996

- Zvi Shiller and S. Sundar will present “Emergency Maneuvers of Autonomous Vehicles.”
- L. Alvarez, R. Horowitz and P. Li will present “Link Layer Controller for the PATH AHS Architecture.”

US–Japan Workshop on Post-Earthquake Reconstruction Strategies

Honolulu, Hawaii, February 2-3, 1996

- James Moore, Geunyoung Kim, Rong Xu, Seongkil Cho presented “Rapid Estimation of Network Flows for Freeway Retrofit Decisions.”

Southern California Association of Governments Interagency Modeling Group

Los Angeles, California, March 17, 1996

- James Moore, Geunyoung Kim, Rong Xu, Seongkil Cho presented “Rapid Estimation of Network Flows for Freeway Retrofit Decisions.”

IEEE Solid-State Sensor and Actuator Workshop

Hilton Head Island, South Carolina, June, 1996

- M. Lemkin, B.E. Boser, D.M. Auslander will present “A Fully Differential Lateral Accelerometer with Drift Cancellation Circuitry.”
- Thor J. Juneau, Per Ljung, Albert P. Pisano will present “Dual Axis Vibratory Rate Gyros.”
- Per Ljung will present “Multi-domain CAD using Dual Reciprocity Boundary Elements.”

IEEE Custom Integrated Circuits Conference

May 1996

- M. Lemkin, B.E. Boser will present “A micromachined fully differential lateral accelerometer.”

1995 International Mechanical Engineering Congress & Exposition

(Winter Annual Meeting of the American Society of Mechanical Engineers)

San Francisco, California, November 1995.

- Per B. Ljung, Thor J. Juneau, Albert P. Pisano presented “Micromachined Vibratory Rate Gyro.”

1996 International Mechanical Engineering Congress & Exposition

(Winter Annual Meeting of the American Society of Mechanical Engineers)

Atlanta, Georgia, November 1996

- Thor J. Juneau, Per B. Ljung, Albert P. Pisano will present “Nonlinear Dynamics of Micromachined Rate Gyros.”
- Per B. Ljung will present “Sequential Solutions of Field Equations Using a Single BEM Model.”

Intelligent Vehicles ’95

Detroit, Michigan, September 25-26, 1995

- Bill David presented “Retroreflective Data/Voice Communication Sensor for Cooperative Automatic Vehicle Control.”

Future Transportation Technology Conference and Exposition

Costa Mesa, California, August 7-10, 1995

- Bill David presented “FMCW Sensors for Longitudinal Control of Vehicles.”
- Z. Shiller, S. Sundar presented “Emergency Maneuvers of AHS Vehicles.”

World Car Conference

Riverside, California, January 15, 1996

- Intelligent Transportation Systems (ITS) Session. Stein Weissenberger presiding
- Randolph Hall presented “ITS Applications to Trucking.”
- Hong Lo presented “Advanced Transportation Management Centers.”

Second World Congress on Intelligent Transportation

Yokohama, Japan, November 1995

- Ted Cohn presented “Engineered Visibility Warning Signals: An IDEA Project.”

continued on p 12

Intelligent Sensor

Alice Agogino, Kai Goebel, Satnam Alag

Department of Mechanical Engineering

UC Berkeley

No sensor will deliver accurate information at all times. Many uncertain influences may add noise to sensor readings, or cause a total malfunction of the sensor. To avert these effects, and to maintain the high level of safety that is an integral part of intelligent transportation systems, we propose a fault tolerant supervisory control architecture. It consists of five main modules: sensor validation, sensor fusion, fault diagnosis, hazard analysis, and a safety decision maker.

Two methods have been identified and developed for these modules. One is based on probability theory, the other on fuzzy logic. The probability approach models the sensors, along with potential failures, as probabilistic events and adaptively estimates the probabilities of these events on-line. For this purpose vector dynamic probabilistic networks have been developed, and rules have been derived for inference in these networks. Such networks provide a theoretically sound method for modeling the uncertainty inherent in a system. The process of sensor validation, data fusion, and fault diagnosis is thus converted to a decision-analytic problem, where consistent decisions can be made to maximize expected utility.

The fuzzy logic approach makes use of fuzzy time series for predictions, validation gates for fusion, and abductive inference for diagnosis. The fuzzy validation gates are bound by the physical possible changes from one time step to the next. Curves denoting confidence values for each sensor reading are fitted into the validation gates, which have their maximum value at the predicted value (calculated through the fuzzy time series predictor) and whose shape reflects a particular sensor behavior. Sensor fusion takes place using a weighted average of each sensor reading with its respective confidence value. For diagnosis, a ranking scheme considers to what degree symptoms were observed, as well as the strength of the connection between rules and symptoms, i.e., to what degree a fault causes a symptom.

Data from experiments are used to allow proper modeling of sensor behavior in a variety of conditions, e.g., vibrations, fog, rain, etc. Simulations, including both open and closed loop experiments, show that a significant improvement of sensor data fidelity can be achieved through sensor validation and fusion.

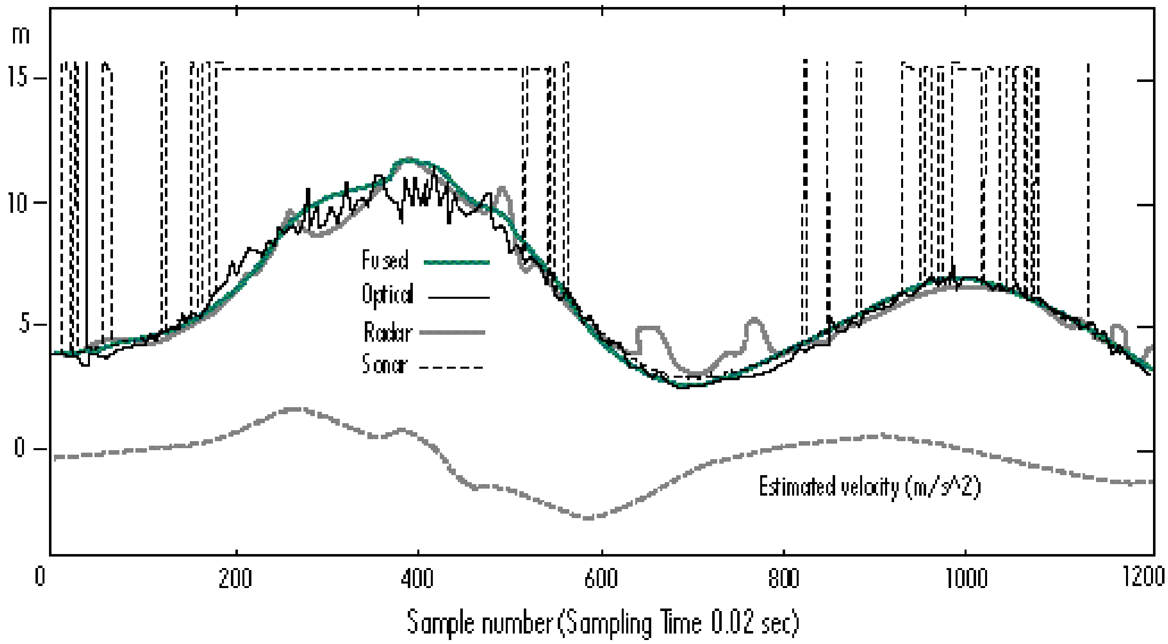
References

Agogino, A., S. Alag, and K. Goebel. 1995. “A Framework for Intelligent Sensor Validation, Sensor Fusion, and Supervisory Control of Automated Vehicles in IVHS.” Intelligent Transportation: Serving the User through Deployment. Washington, DC: Proceedings of the 1995 Annual Meeting of ITS America, pp. 77-87.

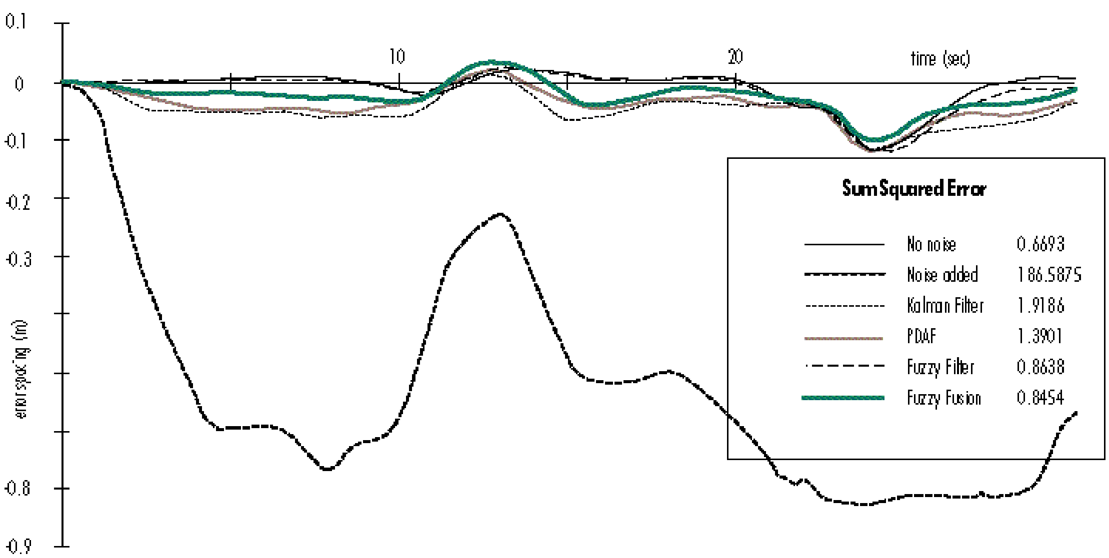
Agogino, A., K. Goebel, and S. Alag. 1995. “Intelligent Sensor Validation and Sensor Fusion for Reliability and Safety Enhancement in Vehicle Control.” Berkeley, CA: California PATH Research Report, November 1995, UCB-ITS-PRR-95-40.

Alag, S., K. Goebel, and A. Agogino. 1995. “Intelligent Sensor Validation and Fusion Used in Tracking and Avoidance of Objects for Automated Vehicles.” Seattle, WA: Proceedings of the ACC 1995.

Validation and Fusion



Open loop sensor validation and fusion applied to distance readings obtained from three longitudinal sensors (radar, sonar, optical)



Effect of closed loop sensor validation and fusion applied to data obtained from three longitudinal sensors on error spacing between follower cars

Fall and Winter Bring Visitors

INRETS

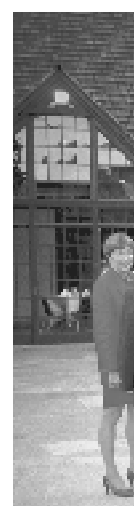
Fifteen researchers from the Institut National de Recherche Sur Les Transports et Leur Securité, headquartered in Lyon, France, attended the Joint University of California Institute of Transportation Studies/PATH–France Workshop, held October 24-25, 1995. INRETS participants included Director-General Jacques Rousset, Deputy Director Jean-Pierre Medevielle, and former director Claude Lamure.

News of PATH's work on automatic vehicle control brought many visitors to the Golden Gate Fields test track. Above, UC Berkeley Transportation Center Director Mel Webber, UCB ITS Director Adib Kanafani, and US Department of Transportation Research and Special Programs Administrator D. K. Sharma watch a demonstration. Below left, San Francisco television station KRON sent reporter Greg Lyon to cover lateral-control tests.

Wei-Hua Lin, PATH

Stuart Russell, UCB

Directors Pravin Varaiya, PATH; Adib Kanafani, UCB ITS



A highlight of

hers Sei-Bum Choi (far left) and Han-Shue Tan (center) describe magnetic sensor system to INRETS visitors

Hamed Benouar, Caltrans Advanced Highway Systems Office Chief, with INRETS Director-General Jacques Rousset, Deputy Director Jean-Pierre Medevielle, and former director Claude Lamure

Program-Wide Meeting

The PATH Program-Wide Research Meeting, held at the Richmond Field Station from October 12-13, 1995, brought members of the PATH partnership together to present new research and exchange ideas informally. A complete listing of the presentations delivered is on page 12.

Poly

Masayoshi Tomizuka, UCB

Mireille Broucke, PATH

James Moore, USC

Dolf May, UCB ITS

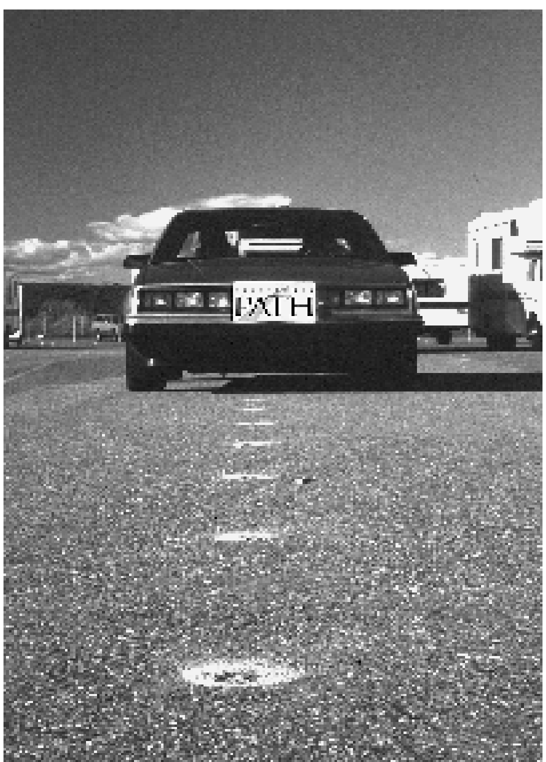
de Meeting was dinner at the Brazil Room in Berkeley's Tilden Park

Ray Patron, Bill Okwu, Caltrans;
Akash Deshpande, PATH

Magnetic Sensors for Automatic Steering Control

Han-Shue Tan, Satyajit Patwardhan
PATH

For a human being, the most conventional vehicle control system, seeing the lane markings on the road is simple. For an automatic steering system – the cameras and trunk full of computers that comprise a typical vision-based system –"seeing" the road is more complicated. For a vehicle to follow a road automatically, the road must first be marked by some indicators that define it. The vehicle then employs appropriate sensors to measure the corresponding physical properties of these road markings and to determine its own location with respect to them. The on-board intelligence, based on these relative locations, then commands the actuator to steer the vehicle and follow the road. The PATH automatic steering control system is based on magnetic markers: the "eyes" are magnetometers.



Magnetometer-eye view of the roadway and markers

A magnetic marker implanted under the roadway surface sends out a specific magnetic field. A three-axis magnetometer, located just below the front bumper of the vehicle, picks up the total magnetic strength at the sensor. In principle, one can obtain the relative location of the magnet with respect to the sensor by comparing the measured magnetic strength with a 'map' of the magnetic field produced by that particular variety of magnetic marker. The lateral component of the relative location can then be used to control the vehicle's automatic steering function. However, practice is usually more difficult than principle, and many factors complicate the process, among them the earth's own magnetic field. At the sensor location (which to protect the sensor cannot be too close to the ground) the magnetic strength of the magnetic markers is comparable to that of the earth. As a result, it is impossible to utilize the measurement without knowing the earth's magnetic field at every marker location. To make the situation worse, the vehicle's movement, the surrounding environment, and any nearby ferrous material all affect the earth's field at the sensor. Fortunately, the magnetic strength midway between two adjacent magnetic markers offers a convenient estimate of the earth's field, provided that the two markers are placed sufficiently far apart. This, however, prohibits any truly continuous measurement of the relative displacement between vehicle and road markers.

In the system currently implemented by PATH, we have adopted a simpler signal processing algorithm, using only vertical and lateral magnetic field measurements. The lateral displacement of the vehicle at the marker position can be obtained through a peak detection algorithm where the effects of the vehicle's vertical oscillations are removed using a

Placing a magnetic marker

calibrated two-dimensional magnetic field map. The major advantage of this system is that it offers a relatively simple and very robust lateral displacement measurement of the vehicle. The system works equally well under such adverse conditions as rain, snow, and low visibility. However, it is indeed a discrete-time sensing scheme where the sampling frequency depends on both the spacing of the magnets and on the vehicle speed.

The choice of the magnetometer depends on various factors: spacing between markers, height of the sensor, and characteristics of the magnetic field, as well as the required range and resolution of the lateral displacement. There are basically four different kinds of magnetometers on the market. In decreasing order of sensitivity and increasing order of range, they are: super quantum interference device (SQUID), fluxgate, magnetoresistive, and Hall effect sensors. We are currently using a fluxgate magnetometer, which has good sensitivity from a few microgauss to several gauss, and which could be relatively inexpensive if mass produced. Given possible price drops below ten dollars each under the automatic highway scenario, multiple magnetometers could be used to ensure a larger measurement range and provide redundancy protection to improve system integrity.

PATH is currently considering several ways of improving the magnetic-based system: the implementation of multiple magnetometers to increase the sensing range; the development of various sensor fusion techniques with other on-board sensors to improve the viability of the system during lane change and emergency maneuvers; and finally, the investigation of different signal processing methods to desensitize the magnetic effects from rebar under the roadway and from steel bridges.

Coming out of a slippery turn under automatic control, hands off – the system works equally well under adverse conditions

PATH Research Presented

continued from page 5

PATH Program–Wide Research Meeting

Richmond Field Station, October 12-13. 1995

Welcome — Adib Kanafani, Hamed Benouar

Overview of ATMIS, Plenary I — Stein Weissenberger

Overview of Systems, Plenary II — Randolph Hall

Sensors — Chair: Bret Foreman

New Developments in Stereopsis for Vehicle Control — Jitendra Malik

Micro Inertial Instrument Research Update: Recent Research Results at BSAC — Albert Pisano

Sensor Fusion — Alice Agogino

Traffic Modeling — Chair: Hong Lo

Incident Detection — R. Jayakrishnan

Developing Simulation Tools for ATMIS — Alex Skabardonis

ITS Object-Oriented Database — Aleks Gollu

Vehicle Control I — Chair: D. Swaroop

Fault Detection — Jason Speyer

Optimal Maneuvers — Zvi Shiller

Infrastructure Managed Vehicle Following: Microscopic Control Design — Petros Ioannou

Field Operational Tests I — Chair: Robert Tam

Smart Call Box — James Banks

TravInfo — Stein Weissenberger

California Testbed — Will Recker

Safety — Chair: Raja Sengupta

Evaluation of Platoons: Safety/Comfort/Performance — Benson Tongue

Performance Assessment and Testing of Sensors for Lateral Control of Vehicles — Andy Segal

Surveillance — Chair: Joe Palen

Advanced Sensing Technologies — Carl MacCarley

A Machine Vision Based Surveillance System — Jitendra Malik

Freeway Surveillance Utilizing Cellular 911 Calls — Alex Skabardonis

Vehicle Control II — Chair: Han-Shue Tan

Combined Lateral and Longitudinal Control I — Karl Hedrick

Combined Lateral and Longitudinal Control II — Masayoshi Tomizuka

Longitudinal Control of Heavy Duty Vehicles — Ioannis Kanellakopoulos

Systems, AHS Design — Chair: Datta Godbole

Continuous Platooning — Wei Ren

Feasibility Study of Fully Autonomous Vehicles Using Decision-Theoretic Control — Stuart Russell

Regulation, Coordination, and Link Layer Controller Design for the PATH AVCS Architecture Degraded Modes of Operation — Roberto Horowitz, Shankar Sastry

System Integration — Chair: Randolph Hall

National System Architecture — Mark Hickman

Transportation Management Centers — Hong Lo

Simulation of ATMIS Strategies — Adolf May

Modeling — Chair: Mireille Broucke

Modeling of Hybrid Automated/Non-Automated Freeway — Carlos Daganzo, Michael Cassidy

Network and Link Layer Models — Mireille Broucke, Pravin Varaiya

AHS Emissions — Matthew Barth

Platoon Aerodynamics: Recent Wind Tunnel Results, Upcoming Full-Scale Tests — Fred Browand

Field Operational Tests II — Chair: Pat Conroy

SCOOT — Carl MacCarley, James Moore, R. Jayakrishnan

Integrated Freeway/Arterial Adaptive Signal Control — Carl MacCarley, James Moore, R. Jayakrishnan

Mobile Surveillance — Stephen Hockaday

CalPoly Testbed — Stephen Hockaday

Systems, AHS Design — Chair: Aleks Gollu

AHS Status — Steve Shladover

SmartPATH — Farokh Eskafi, Delnaz Khorramabadi

SmartAHS — Akash Deshpande, Aleks Gollu

Transit — Chair: Mark Hickman

Transit Needs for the Visually Impaired — Reginald Golledge

Smart Traveler — Genevieve Giuliano

Advanced Information and Transit Systems — Mark Hickman

Inertial Sensors

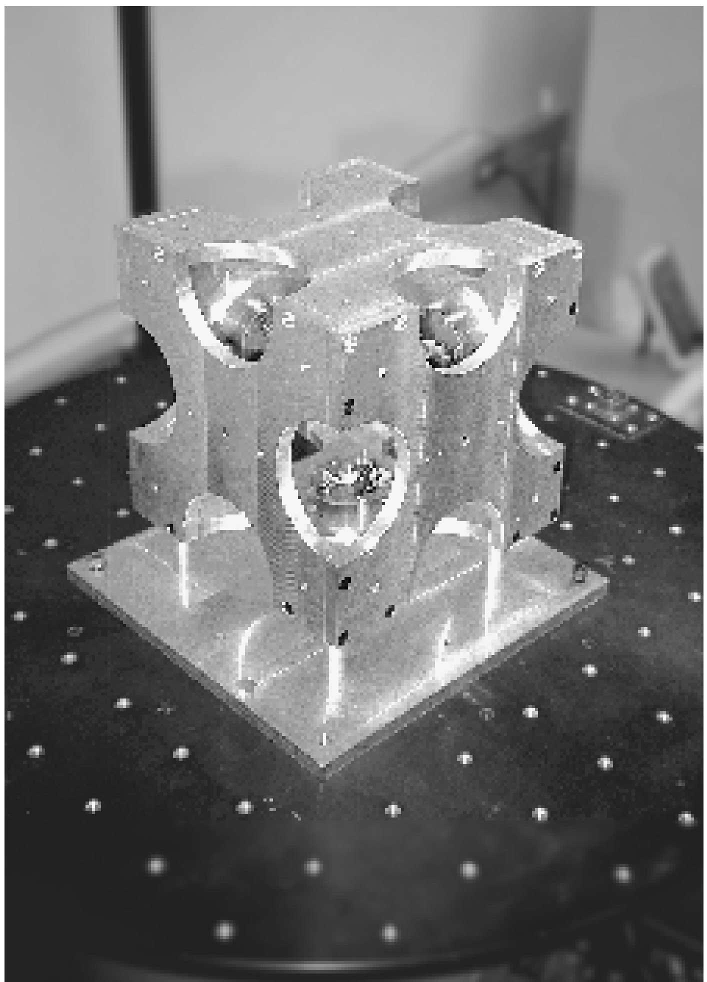
continued from page 1

signal conditioning circuitry, analog filtering and analog to digital conversion subsystems. The third and most challenging task is to develop algorithms for sensor calibration and data processing and the software for an embedded DSP computer. The final task is to develop methods for testing the performance of inertial sensors and IMUs using system identification in a testing facility. All four tasks were pursued aggressively during 1995. The result, a first generation "proof of concept" multisensor system, is shown on the inertial test stand as shown.

Once developed, prototypes will be implemented on test vehicles and will be made available to other research groups. Currently we are focusing on a first generation six-sensor module that could replace single-axis accelerometers in each PATH vehicle and that will measure true acceleration for longitudinal control. The system will measure six degrees of freedom for each vehicle. These measurements can be used to improve the ride quality in a platoon. The choice of integrated sensors has resulted in a tenfold price reduction, with the total system component cost being under $100, compared to over $1000 for a single accelerometer at present.

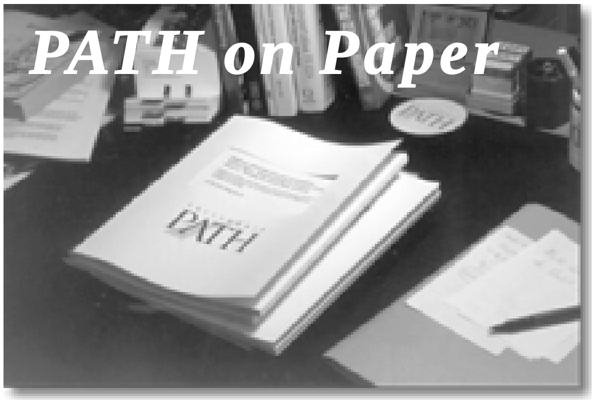
The first generation (ADXL05) integrated sensors do suffer, however, from numerous errors. To achieve required performance, complex calibration and processing must be performed on the data provided by each sensor. Mathematical models and software algorithms have been developed to correct for sensor errors using a "generic" approach. This approach allows users to adjust parameters to accommodate sensors with different characteristics or a different number of sensors per system.

BSAC researchers are expected to provide a broad new array of linear multiple-axis accelerometers and angular rate gyroscopes with improved accuracy in the future. Such sensors will greatly enhance the current IMU performance, and will allow us to configure systems for new applications.



Prototype vehicle multi-sensor system (three of six sensors installed) mounted on inertial test stand

Please visit the PATH Sensor Group Web Site at http://www.path.berkeley.edu/~webed/sensor/sensor.html



Below is an update on some recent PATH publications.
A price list that includes research reports, working papers, technical memoranda, and technical notes can be obtained from the: Institute of Transportation Studies Publications Office
University of California
109 McLaughlin Hall, Berkeley, CA 94720
510-642-3558, FAX: 510-642-1246.

Abstracts for all PATH research publications can be obtained via the PATH World Wide Web home page on the internet:
http://www.path.berkeley.edu

PATH Research Papers

UCB-ITS-PRR-95-41	Los Angeles Smart Traveler Field Operational Test Evaluation, Genevieve Giuliano, Randolph W. Hall, Jacqueline M. Golob, December 1995, $35.00
UCB-ITS-PRR-95-42	Fuzzy Throttle and Brake Control for Platoons of Smart Cars, Hyun Mun Kim, Julie Dickerson, Bart Kosko, December 1995, $10.00
UCB-ITS-PRR-95-43	A Theory of Traffic Flow in Automated Highway Systems, M. Broucke, P. Varaiya, December 1995, $10.00
UCB-ITS-PRR-95-44	Fuzzy Traffic Density Homogenizer for Automated Highway Systems, C.C. Chien, P. Ioannou, C.K. Chu, December 1995, $10.00
UCB-ITS-PRR-95-45	A Dynamic Visualization Environment for the Design and Evaluation of Automatic Vehicle Control Systems, Z. Xu, December 1995, $10.00
UCB-ITS-PRR-96-01	Longitudinal Control Development for IVHS Fully Automated and Semi-Automated Systems: Phase II, J.K. Hedrick, J.C. Gerdes, D.B. Maciuca, D. Swaroop, V. Garg, January 1996, $20.00
UCB-ITS-PRR-96-02	Integrated Maneuvering Control Design and Experiments: Phase 2, J.K. Hedrick, M. Pantarotto, T. Yoshioka, Y-H Chen, T. Connolly, V.K. Narendran, January 1996 $25.00
UCB-ITS-PRR-96-03	Formal Specification and Verification of the Entry and Exit Maneuvers, Sonia Sachs, Pravin Varaiya, February 1996, $15.00
UCB-ITS-PRR-96-04	Stage Definition for AHS Deployment and an AHS Evolutionary Scenario, H.-S. Jacob Tsao, February 1996, $10.00
UCB-ITS-PRR-96-05	Constraints on Initial AHS Deployment and the Concept Definition of a Shuttle Service for AHS Debut, H. -S. Jacob Tsao, February 1996
UCB-ITS-PRR-96-06	Transportation Modeling for the Environment: Final Report, Matthew J. Barth, Joseph M. Norbeck, February 1996, $5.00

PATH Working Papers

UCB-ITS-PWP-96-01	Public Transit Use by Non-Driving Disabled Persons: the Case of the Blind and Vision Impaired, Reginald G. Golledge, C. Michael Costanzo, James Marston, January 1996, $10.00
UCB-ITS-PWP-96-02	LANE-OPT Users Manual Version 1.0, David Lotspeich, Randolph W. Hall, March 1996
UCB-ITS-PWP-96-03	Optimized Lane Assignment on an Automated Highway, Randolph W. Hall, David Lotspeich, March 1996

PATH Technical Notes

Tech Note 95-08	A Continum Theory of Traffic Dynamics for Freeways with Special Lanes, Carlos F. Daganzo, December 1995, $10
Tech Note 95-09	A Simple Physical Principle for the Simulation of Freeways with Special Lanes and Priority Vehicles, Carlos Daganzo, Wei-hua Lin, Jose M. del Castillo, December 1995, $10

PATH Seminars

These interdisciplinary seminars are usually held every Wednesday at noon in 3110 Etcheverry Hall on the UC Berkeley campus. For an invitation, please contact Mireille Broucke, *mire@oriel.eecs.berkeley.edu*.

PATH seminar announcements are available on the PATH WorldWide Web home page at *http://www.path.berkeley.edu*. For more information on a particular seminar, please contact the authors at their respective departments.

January 31
Robust Control of Nonlinear Instabilities with Applications
Hua Wang
United Technologies Research Center
East Hartford, Connecticut
Dr. Wang focused on the control of nonlinear instabilities in high performance engineering systems.

January 31
Performance Robustness of Nonlinear Feedback Systems
Ian Fialho
University of Minnesota
Dr. Fialho discussed issues related to the performance and robustness of nonlinear feedback systems over L-infty.

February 14
Evaluation of the SIRIUS (Système d'Information Routière Intelligible aux Usagers) Traffic Management and Traveler Information System in Paris
Jean Orselli
Head of the General Council of Bridges and Roads, National Department of Transportation, France
M. Orselli discussed the evaluation process, preliminary findings, and the future of such systems in France.

February 24
When are High-Occupancy Vehicle Lanes More Effective than General Purpose Lanes?
Joy Dahlgren, PATH
Adolf May
Institute of Transportation Studies, UC Berkeley
In many typical situations HOV lanes are more effective only when there is a high level of delay and a high initial proportion of HOVs

March 22
Can the Objective and Solutions of the Dynamic User-Equilibrium Models Always Be Consistent?
Wei-Hua Lin, PATH
If queuing behavior is represented in the model at a minimal level, the solution to the conventional DUETA model may not necessarily converge to or approximate the Wardropian user-equilibrium condition in the dynamic sense as defined by many researchers.

April 5
Optimizing Large Scale Transportation Systems: Models and Methods
Cynthia Barnhart
Massachusetts Institue of Technology
Dr. Barnhart described some models and solution strategies for a variety of transportation problems,including airline crew scheduling and airline fleet assignment.

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- ***A special issue featuring Field Operational Tests***
- ***A report on ITS America***
- ***Conference Updates***
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